International Activities in Small Satellites; Comparisons with U.S. Programs

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Abstract:

Despite relatively low levels of Government funding when compared with U.S. small satellite activities, the international small satellite community has achieved a number of impressive successes. These range from the impressive imagery transmitted from the University of Surrey's UoSAT-5 to the demonstrated small satellite launch system versatility and affordability of the Ariane Auxiliary Structure for Space Payloads (ASAP). Capabilities exist in a growing number of countries outside of the United States to design, fabricate, and in some cases launch small satellites into low earth orbit. Activities in India and Israel are being joined by emerging space programs in such countries as Portugal, Korea and Pakistan, where the affordability of small satellite systems provides a near-term approach for achieving a space systems capability. The international community has also developed the supporting structure to encourage and foster a new generation of space scientists who have the understanding and vision to recognize the potential applications for small satellite systems. A number of university & small business consortiums have been established in the international small satellite community as a means of providing a continuing source of trained small satellite engineers and scientists. Such programs as the University of Bremen/OHB Systems and the University of Surrey/Surrey Satellite Technology Ltd. are examples of these consortiums that are actively pursuing small satellite development programs.

In contrast, the United States has had a much stronger infusion of government funding to support small satellite development programs. Although one might expect this to result in a head start for the U.S. small satellite industry compared with international small satellite programs, it is not entirely clear that the U.S. small satellite industry has capitalized on its advantages. This paper presents an update on ongoing developments in small satellite programs in the International community along with comparisons of the relative strengths and weaknesses of the U.S. and international programs. Summary comments are provided on the implications of the differences between the U.S. and international small satellite activities, along with recommendations on improvements to the U.S. program.

The basis for this paper is a compilation of information gathered by the author over the last year through involvement in the small satellite community as well as participation in a number of related activities. Included were the author's: Assessment of Small Satellite Technologies in Europe conducted for the Office of Naval Research, London office in July 1991 [1]; Chairmanship of the 1991, 1992[2] (and 1993) SPIE (International Society of Optical Engineering) Small Satellite Conference held in Orlando Florida as part of the annual SPIE Aerospace Sensing Symposia; Participation in the May 1992 ISSO Small Satellite Conference in Washington, D.C. as a Panel Chairman on International Small Satellite Programs; and support of various government research and development activities in small satellite development programs.

Program Comparisons

A comparison of U.S. and International activities in small satellite technologies would be incomplete without an update on the recent and ongoing small satellite development activities in the U.S. and abroad. First, a discussion of U.S. Programs.

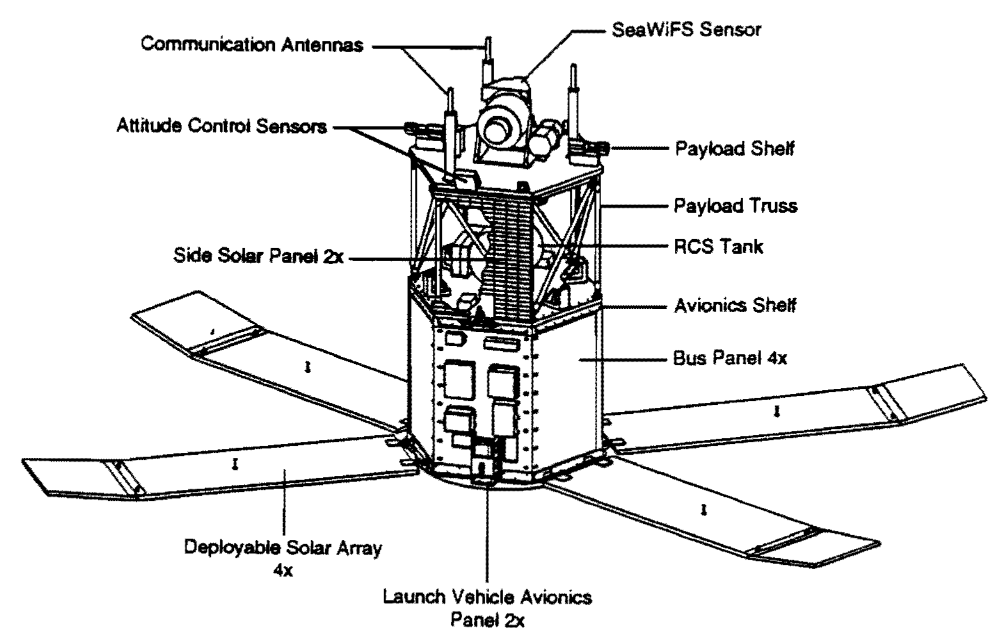

Figure 1. The Orbital Sciences Corporation SeaStar Satellite[3]

U.S. Small Satellite Activities

Principal funding for U.S. small satellite activities has been from the Department of Defense, with a few commercial program exceptions. The exceptions include NASA's initiation of the OSC SeaStar (shown in Figure 1 above) remote sensing small satellite program in 1991, the launch of the Orbital Sciences Corporation (OSC) Orbcomm-X onboard the French Ariane IV launch vehicle in July 1991, the continued funding by the National Aeronautics and Space Administration (NASA) of the COMET recoverable satellite program, and the Department of Energy/Los Alamos National Laboratories (DOE/LANL) funding of the AeroAstro Corporation's Alexis remote sensing satellite, awaiting launch on OSC's Pegasus 3. Representative U.S. Department of Defense small satellite programs are listed below in table 1.

Satellite System	Sponsor	Launch Date	Launch Vehicle
MACSAT 1 & 2	DARPA	May 1990	Scout
CRO 1 to 3	SDIO	April 1991	Space Shuttle
REX	Air Force	June 1991	Scout
SALT	Navy	canceled in 1990	none
ProFile	Navy	canceled in 1991	none
Microsat 1 to 7	DARPA	July 1991	Pegasus 2
STEP 1 to 3	Air Force	awaiting launch	Pegasus & Taurus
DSPSE	SDIO	1994	Atlas

Table 1. Representative U.S. DOD Sponsored Small Satellite Programs

One principal exception to the predominance of U.S. government funded small satellite activity is the active program in small satellite development, fabrication and launch conducted by the Radio Amateur Satellite Corporation (AMSAT), which has a history of successful small satellite activities dating back to the launch of OSCAR 1 in 1961. The AMSAT heritage carries through the OSCAR 22 (UoSAT-5) satellite, launched in July 1991 onboard an Ariane IV. AMSAT is an international organization, staffed buy extremely talented volunteers. In many ways it provides a model organization for innovation in the development of small satellite systems. Because of its amateur and not-for-profit nature, I have not included it in these discussions of government or commercial funded programs. However, the influence of the AMSAT participation and involvement in international small programs is widespread and has spawned a number of other satellite activities and development programs.

Equally important to the satellite development programs themselves are the educational programs and infrastructure necessary to initiate and sustain a small satellite industry. Educational programs focused on small satellite technologies provide the new generation of trained small satellite technologists with the vision to develop new applications for small satellite systems. The infrastructure, with such components as launch systems. ground stations, and data processing capabilities, are also necessary elements of a successful small satellite industry.

Educational programs in the U.S. that include the design, development and operation of small satellites are far and few between. A number of academic program include design studies, but few develop and operate hardware. Examples of some prior and current academic activities that include the development and operation of space hardware are listed below:

- Until its re-entry, the NASA Solar Mesosphere Explorer (SME) satellite was controlled by the University of Colorado at Boulder. The control facility, located on the university campus, supported an active educational program in satellite systems and control software development, including opportunities for hands-on student involvement in a NASA satellite program.

- Weber State University in Ogden, Utah, has developed an undergraduate program at its Center for AeroSpace Technology (CAST), which has supported the fabrication and on-orbit operation of an AMSAT communications and imaging satellite, as well as support of high school space technology workshops

- The University of Alabama at Huntsville supports a student-lead project on tethered small satellites (SEDSAT) scheduled for launch on a Delta II in late 1993.[4]

Although these programs represent individual examples of educational activities focused on the development of small satellite systems, relatively few educational programs exist in the U.S. that can provide hands-on training for future technologists in the emerging small satellite industry.

The supporting infrastructure, including ready access to affordable launch opportunities, is does not support the development of entry-level small satellite systems in the U.S. This is because the high total cost for launching a satellite from a U.S. developed launch vehicle provides an insurmountable barrier for organizations desiring to conduct space experiments with limited funds. With lack of clearly defined interfaces for piggyback flight opportunities on large U.S. launch vehicles, such as the McDonnell Douglas Delta series and General Dynamics Atlas series, the OSC Pegasus launch vehicle offers the only other demonstrated entry-level orbital launch opportunity. The entry cost for Pegasus is well in excess of $ 10 million dollars to put a small satellite into low earth orbit, which is often out of reach for many startup or university level programs. To their credit, the McDonnell Douglas Delta launch vehicle organization has defined a multiple satellite dispenser for small satellite launches, and has investigated the feasibility of co-manifesting smaller payloads [5], but they have not developed a well defined small payload launch interface that is as readily available and as low cost as the French Ariane ASAP ring. In terms of other U.S. small satellite launch capabilities, the current LTV Scout launch vehicle is coming to the end of its service life, and other launch vehicles such as Conestoga and Taurus have yet to be demonstrated.

European support

The international community is developing at a steady pace, despite their relatively low levels of government funding. Defense funding for international small satellite programs has been relatively low compared to programs in the United States. Despite the "wait and see" approach that the existing European space industry has taken to the small satellite and small launch vehicle industries, a number of active small satellite programs are emerging on the international front. The principal appeal of small satellites outside of the U.S. is for developing countries who do not have the funds to support large budget space programs, and small organizations who are also working on limited budgets. A representative listing of recent and ongoing international small satellite programs is provided in the following paragraphs.

<u>United Kingdom</u> - The University of Surrey ***UoSAT*** series, 1 2 & 3 have provided more than 15 orbit years experience with small communications satellites. The launch of UoSat-5 (shown in Figure 2) in July 1991 added the dimension of remote imaging to the UoSAT accomplishments. The onboard camera regularly provides 1km resolution imagery of sights selected from uploaded commands. Imagery can be downloaded by amateur radio hobbyists with their backyard antennas.

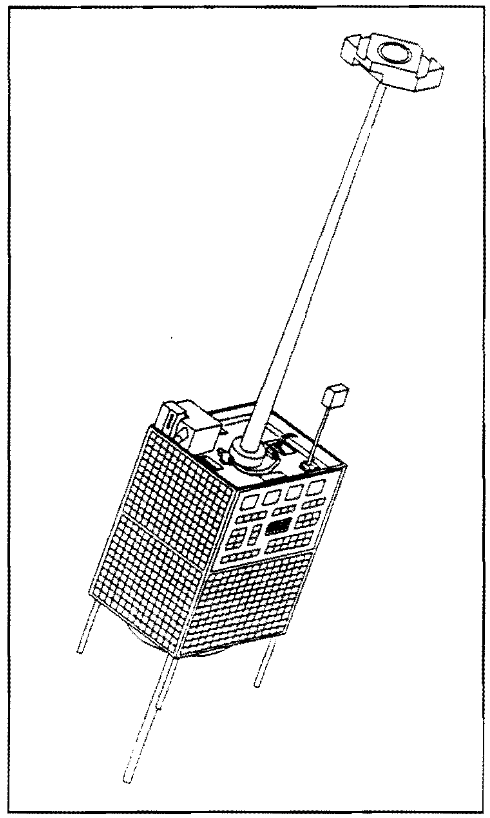

Figure 2. UoSAT-5

<u>Berlin Technical University</u> - ***Tubsat***, a 70 lb. technology demonstration satellite launched from the Ariane ASAP ring on July 16, 1991. Tubsat was designed to conduct digital data relays with portable transmitters[6]

<u>University of Bremen</u> - ***Bremsat***, a Shuttle Get Away Special Can (GAS CAN) experiment scheduled for launch in early 1993. Bremsat will conduct a number of scientific experiments during its short orbit and while re-entering the atmosphere [7]

<u>Korea</u> - *KITSAT-A*, sponsored by the South Korean Advanced Institute of Science and Technology and fabricated by the University of Surrey, has a 50 kg launch weight and will provide 400 meter resolution Earth imaging and amateur radio and educational program relay capabilities [8]. The launch of Kitsat-A is the first step in Korea's development of a satellite manufacturing capability. The $ 12 million dollar investment in Kitsat-A and a subsequent technology transfer program

includes training of students at the University of Surrey, establishment of a ground station in Korea, and support for Korea to build its own satellite at a Korean facility over the next two years[9] .

France - *S 80/T*, sponsored by the French Space Agency, CNES to assess frequency bands that could be used for constellations of small relay satellites - built by the University of Surrey, Matra Marconi Space and Dassault Eletronique [10]

Israel - *Offeq-2*, a 172 kg spin stabilized satellite launched on April 3, 1990 and re-entered on July 9, 1990. Offeq-2 provided in-orbit communications and control demonstrations to further develop and prove the Israel Aircraft Industry's capabilities in satellite technology development

Pakistan - ***BADR-A***, shown in Figure 3, was launched in July 1990 from a Chinese Long March 2E booster the 50 kg satellite had a life span of 6 months and included store-and-forward communications experiments. Pakistan is fabricating a second satellite, BADR-B, for launch in 1994 as part of a national program to build and operate remote-sensing spacecraft - BADR-B will weigh 50 kg and have an operational life of 2 to 3 years... it will carry a charge coupled device camera to test Pakistan's capability to transmit images from space [11]

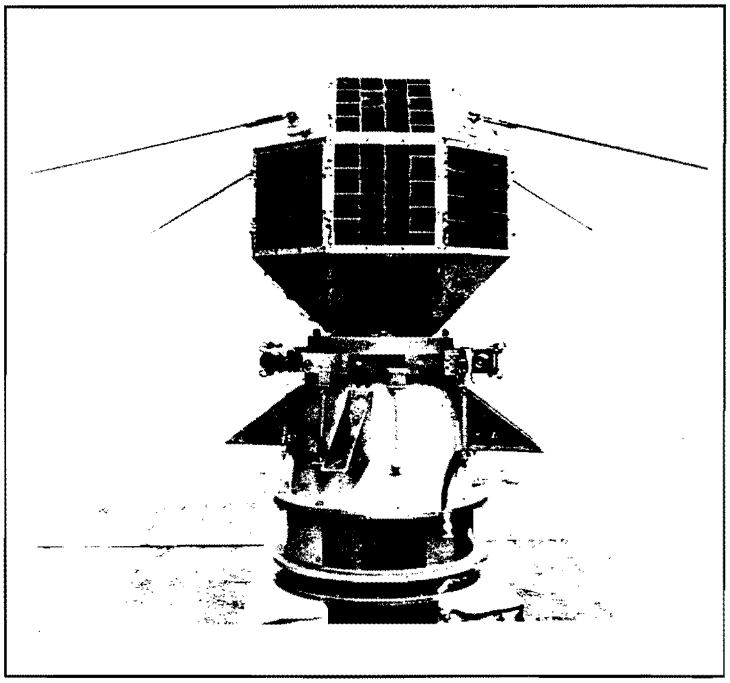

Figure 3. Badr-A on its ejection system

India is a principle example of a country that has advanced from the launch of small remote sensing satellites, ***ROHINI D1*** and ***D2*** and ***SROSS*** in the 1980s to larger telecommunications satellites with the launch of Insat 2A on July 9, 1992 by an Ariane IV. Insat 2A was developed primarily from Indian technologies and is a follow-on to Insat 1 satellites supplied by Ford Aerospace. Liftoff weight of Insat 2A was 1906 kg. Operation of Insat 2A should help establish India as a producer of modern commercial satellites[12]

Brazil - ***Brazilsat*** , Brazil's first domestically built satellite is scheduled for an upcoming Pegasus Launch. The satellite is sponsored by Brazil's Astronautics Ministry [13]

South Africa - ***Sunsat;*** the University of Stellenbosch outside of Cape Town is leading the efforts in South Africa to develop their own small satellite sytem. The Sunsat concept is for a 50 kg , 3-axis control satellite with geolocation, remote imaging and communications capabilities. The satellite would be similar to the University of Surrey UoSAT series. A mid-1994 launch on Ariane is being evaluated.[14]

Several university/industry consortiums exist for the development of small satellites outside of the U.S. These include the University of Bremen & OHB Systems, and the University of Surrey & Surrey Satellite Technology Limited. Organizations such as these have provided a valuable connection between university sponsored space systems research activities and commercial firms seeking to develop space hardware. Spacecraft technologies such as the UoSAT series, developed by the University of Surrey, have been marketed by Surrey Satellite Technology Limited (SSTL) to other countries, such as Korea (Kitsat), successfully launched on August 10, 1992 from an Ariane IV ASAP ring. SSTL has also support the fabrication of the French S80/T microsatellite launched on the Ariane 42P mission on 10 August 1992 [15]

Space programs are being initiated in many countries, such as Korea and Portugal and Pakistan. These developing programs look to small satellite technologies as an economical way to develop capabilities, educational support activities, and the infrastructure necessary to support emerging space programs. The recent United Nations gathering in Rio de Janeiro, Brazil, for the Conference on Environment and Development highlighted the need for all countries to take an active role in protecting the global environment. Space remote sensing plays a very important role in the capability to monitor and control the environment, and is becoming an increasingly important part of the technology base development programs in many countries outside the U.S. [16] For example:

- The launch of the Korean 50 kilogram KITSAT-A, on August 10, 1992 (as described above) forms an important first step in Korea's quest to build a remote sensing satellite and resident spacecraft manufacturing capability. While Korean Telecomm has initiated a contract with General Electric for fabrication of two telecommunication satellites, Korean students at the Korean Advanced Institute of Science and Technology in Seoul are building a follow-on version of the KITSAT-A that was fabricated by the University of Surrey (SSTL) under a $ 12 million dollar contract for satellite fabrication, educational and system development support. As long as the new South Korean president, to be elected in December 1992, supports space technology, the Korean space programs appear to be on solid footing. [17]

- Pakistan's Space and Upper Atmospheric Commission is currently manufacturing a second research satellite, scheduled for launch in 1994 as part of their national program to develop and operate remote sensing spacecraft. [18] Pakistan's first experimental satellite, the 50 kg Badr-A, was launched in July 1990 from a

Chinese Long March 2E booster. Their second satellite, the 50 kg Badr-B, will include an onboard earth imaging system. Pakistan has a suborbital launch vehicle, the two-stage Shahpar rocket, but has to rely on other countries for orbital satellite launches.

- Portugal began a sustained effort in 1987 to participate in international activities in a broad range of technologies. In 1990 the government decided to develop a national space potential and began investigating options including participation in the European Space Agency (ESA) and development of a resident space industry. The approach that was taken in the near term was to develop a Portuguese satellite, PoSAT, and place it in orbit from an Ariane ASAP launch. The satellite would be built by a European company and would provide Portuguese engineers experience in developing and operating a remote sensing space system. Longer term objectives include the development, launch and operation of a Portuguese built small satellite. The affordability of small satellites developed for the Ariane ASAP launch system was a principal reason for Portugal's choice of this approach to enter the international satellite and space systems industry. [19]

Summary

In comparison, the international small satellite development community has accomplished a lot despite their relatively low levels of government subsidy compared to programs in the United States. With the growing emphasis for development of remote sensing capabilities on an international level, the trend towards the initiation of more space programs outside of the U.S. will probably continue. In emerging countries, it is a logical process for their emerging space industries to look to small satellite systems as an affordable means of developing resident capabilities in space systems technologies and hardware development. At present, these countries look to such organizations as the University of Surrey's Surrey Satellite Technology Limited (SSTL) for assistance in small satellite hardware and technologies. The U.S. small satellite industry may be missing a very important international market.

What can we do in the U.S. to keep from losing ground to the international community in small satellite technologies? We can increase our educational support of small satellite technologies and also develop readily accessible launch interfaces, such as the Ariane ASAP ring, that will lower the financial threshold for participation in small satellite activities by a larger number of organizations. As an interested participant in the U.S. small satellite industry, you can actively encourage the U.S. launch vehicle industry to develop a standard small satellite launch interface. You can also give your verbal, financial, and physical support to the establishment of a more extensive small satellite system educational programs in selected universities. There is an effort underway to develop a role for U.S. schools in earth observation, led by the Satellite Educators Association. [20] More such activities are needed. The University of Surrey in the United

Kingdom has undergraduate, graduate, and doctoral programs in small satellite technologies, with a heritage of successful small satellite launches. No such equivalent program, with a full range of educational options, exists in the United States. Make your desires known, or we risk further loss of ground to the international community in the emerging small satellite industry.

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[1] European Science Notes Information Bulletin, 91-07, DEC 91, "Small Satellite Technology, An Assessment of European Activities", B. Horais

[2] SPIE Small Satellite Conference Proceedings, 1991 & 1992

[3] SPIE Small Satellite Conference, 1992, "PegaStar Spacecraft Concept for Remote Sensing Missions", R. Meurer, et al

[4] SPACE NEWS, February 3, 1992, p. 26 "Students Push for Late 1993 Launch of Tethered Satellite"

[5] AIAA/USU 5th Annual Small Satellite Conference, 1991, " Delta Launch Vehicle Accommodations for Small Satellites" , K. R. Knox

[6] AVIATION WEEK & SPACE TECHNOLOGY, August 5, 1991, p. 61, " Ariane V44 Launches Microsatellites From Four Western Nations Into Orbit"

[7] AIAA/USU 5th Annual Conference, " BREM-SAT Attitude Control at Low Altitudes", A. Ginati

[8] AVIATION WEEK & SPACE TECHNOLOGY, August 17, 1992, p. 23, "U.S. and France Increase Space Ties; Topex Follow-on, Russian Role Sought"

[9] SPACE NEWS, August 24-30, 1992, p. 10, "Kitsat-A Launch is First Step for Korean Space Program"

[10] AVIATION WEEK & SPACE TECHNOLOGY August 17, 1992, p. 23, "U.S. and France Increase Space Ties; Topex Follow-on, Russian Role Sought"

[11] AVIATION WEEK & SPACE TECHNOLOGY, August 10, 1992, p. 46, "Pakistan's Space Agency Building Second Experimental Satellite"

[12] AVIATION WEEK & SPACE TECHNOLOGY, July 27, 1992, p. 57, "India Seeks Larger Role in Commercial Satellite Market"

[13] SPACE NEWS, October 21-27, 1991, p. 2, "Brazilian Satellite to Fly on Pegasus"

[14] SPACE NEWS, August 26-September 8, 1991, p. 21, "South Africans Propose Microsatellite"

[15] AVIATION WEEK & SPACE TECHNOLOGY, August 17, 1992, p. 23, "U.S. and France Increase Space Ties; Topex Follow-on, Russian Role Sought"

[16] SPACE NEWS, June 22-July 5, 1992, p. 19, "Developing Nations Need Space Tools"

[17] SPACE NEWS, August 24-30, 1992, p. 10, "Kitsat-A Launch is First Step for Korean Space Program"

[18] AVIATION WEEK & SPACE TECHNOLOGY, August 10, 1992, p. 46, "Pakistan's Space Agency Building Second Experimental Satellite"

[19] SPIE Small Satellite Conference, 1992, "Rationale for Minisatellites Technology and Policy in Portugal", J. Rebordao, Portugal

[20] SPACE NEWS, March 30, 1992, p. 24 " U.S. Schools are Seeking a Role in Earth Observation"